User Guide for

FEBFL103_L15U008A

8.4 W LED Driver at Universal Line

Featured Fairchild Product:

FL103

Direct questions or comments about this evaluation board to: "Worldwide Direct Support"

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This user guide supports the evaluation kit for the FL103M. It should be used in conjunction with the FL103M datasheet as well as Fairchild's application notes and technical support team. Please visit Fairchild's website at www.fairchildsemi.com.

1. Introduction

This document describes the proposed solution for an universal input 8.4 W LED ballast using the FL103M Primary-Side Regulator (PSR) controller and the FQU2N60C QFET®. The input voltage range is 85 V_{RMS} – 265 V_{RMS} and there is one DC output with a constant current of 350 mA at 24V $_{MAX}$. This document contains a general description of FL103M, the power supply specification, schematic, bill of materials, and the typical operating characteristics.

1.1. Description

This third-generation Primary-Side-Regulation (PSR) and highly integrated PWM controller provides features to enhance the performance of LED illumination.

The proprietary topology, TRUECURRENT™, enables precise CC regulation and simplified circuit design for LED illumination applications. The result is lower-cost and smaller LED lighting compared to a conventional design or a linear transformer.

To minimize standby power consumption, the proprietary Green Mode provides off-time modulation to linearly decrease PWM frequency under light-load conditions. Green Mode assists the power supply in meeting the power conservation requirements.

By using the FL103, LED illumination can be implemented with few external components and minimized cost.

1.2. Features

- Low Standby Power: < 30 mW
- High-Voltage Startup
- Few External Components
- Constant-Voltage (CV) and Constant-Current (CC) Control without Secondary-Feedback Circuitry
- Green-Mode: Linearly-Decreasing PWM Frequency
- Fixed PWM Frequency at 50 kHz and 33 kHz, Frequency Hopping to Solve EMI Problems
- Peak-Current-Mode Control in CV Mode
- Cycle-by-Cycle Current Limiting
- V_{DD} Over-Voltage Protection (OVP)
- V_{DD} Under-Voltage Lockout (UVLO)
- Adjustable Brownout Detector
- Gate Output Maximum Voltage Clamped at 15 V
- Thermal Shutdown (TSD) Protection
- Available in the 8-Lead SOIC Package

1.3. Internal Block Diagram

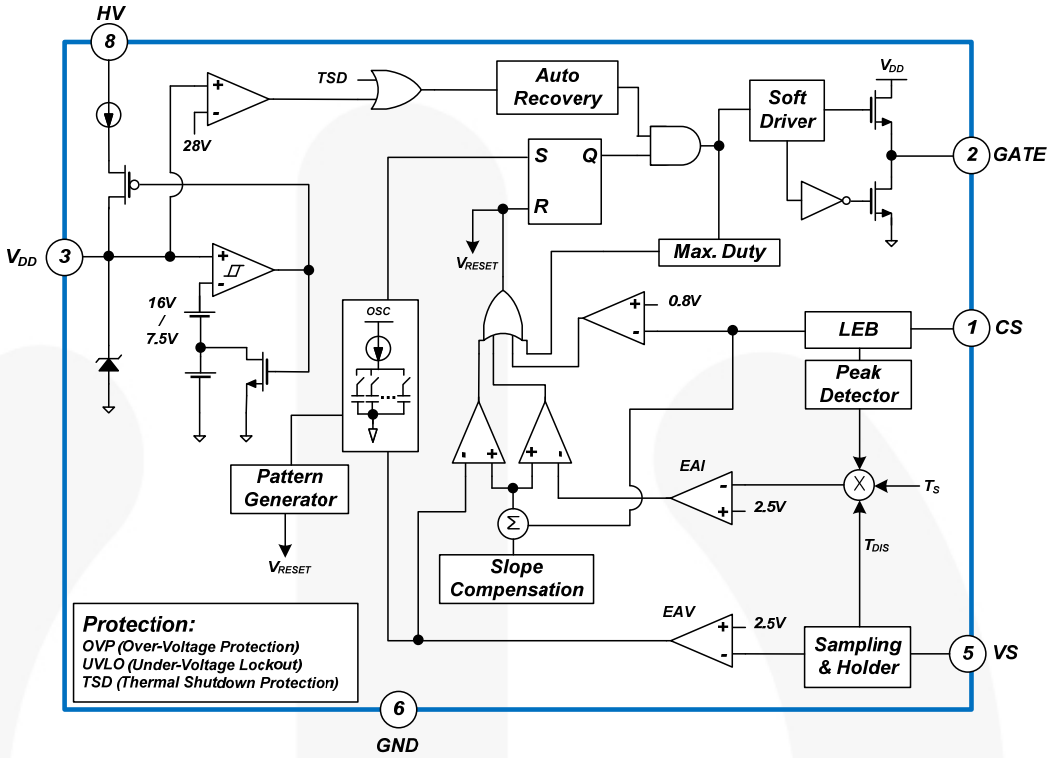


Figure 1. Block Diagram

2. Specification for Evaluation Board

Table 1. Evaluation Board Specifications for LED Lighting Bulb

Main Controller		FL103M
Input	**Frequency Range**	50 Hz ~ 60 Hz
	Voltage Range	85 V_{AC} ~ 265 V_{AC}
Output	**Power**	< 8.4 W
	Voltage	< 24 V
	Current	Typ. 0.35 A
Efficiency	< 87%	
Conduction EMI	Meet Margin of EN55022 conducted EMI: > 7 dBuV	
Board Dimensions	53 mm x 25 mm (Neck: 15 mm x 15 mm)	

All data of the evaluation board were measured under a condition where the board was enclosed in a case and external temperature was around 25°C.

3. Photographs

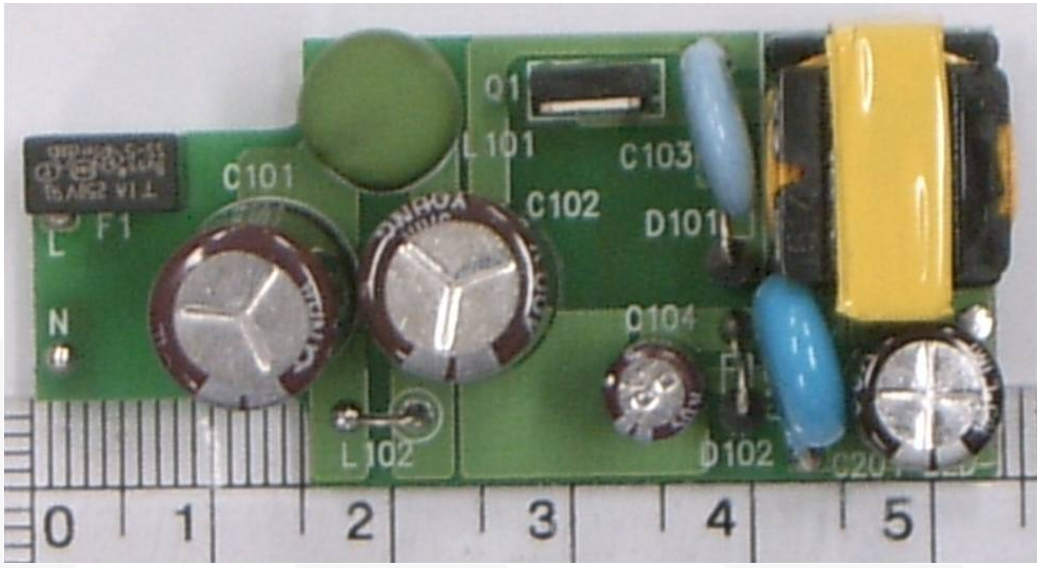


Figure 2. Top View

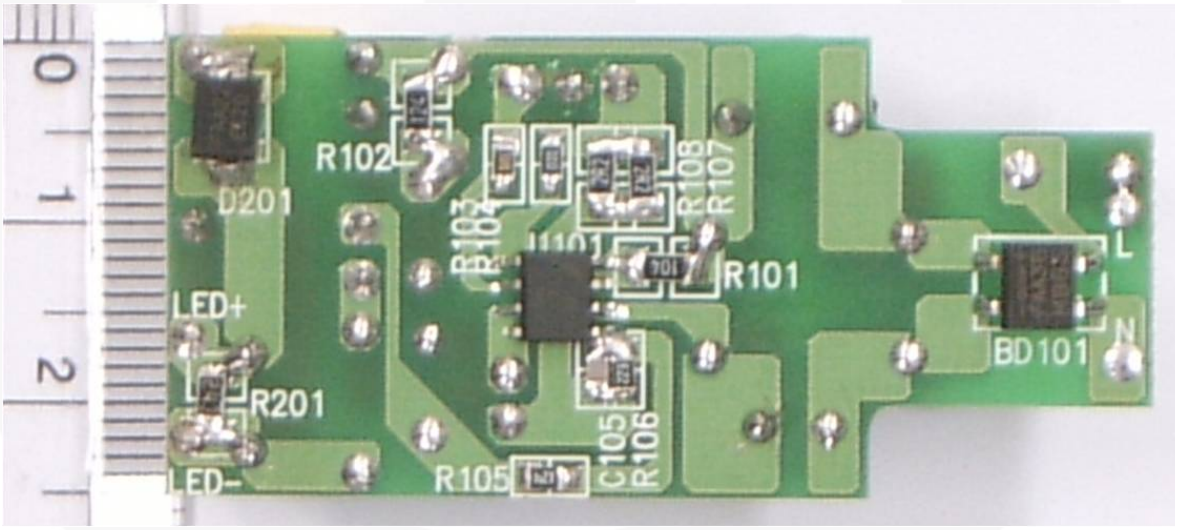


Figure 3. Bottom View

4. Printed Circuit Board

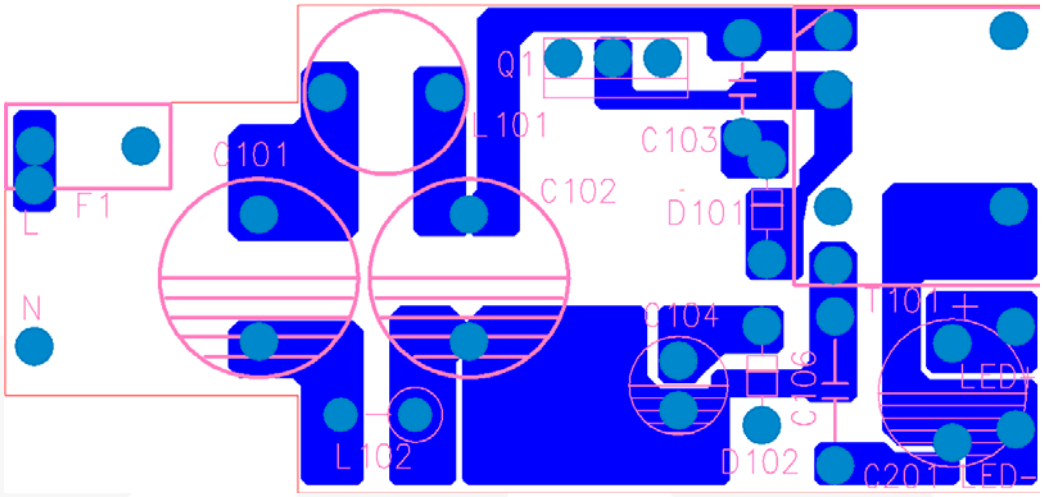


Figure 4. Printed PCB, Top Side

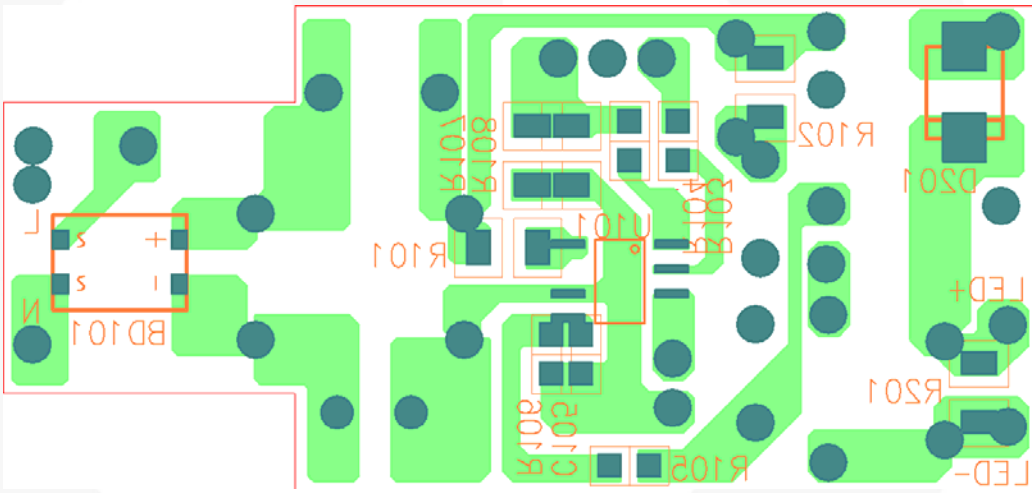


Figure 5. Printed PCB, Bottom Side

5. Schematic

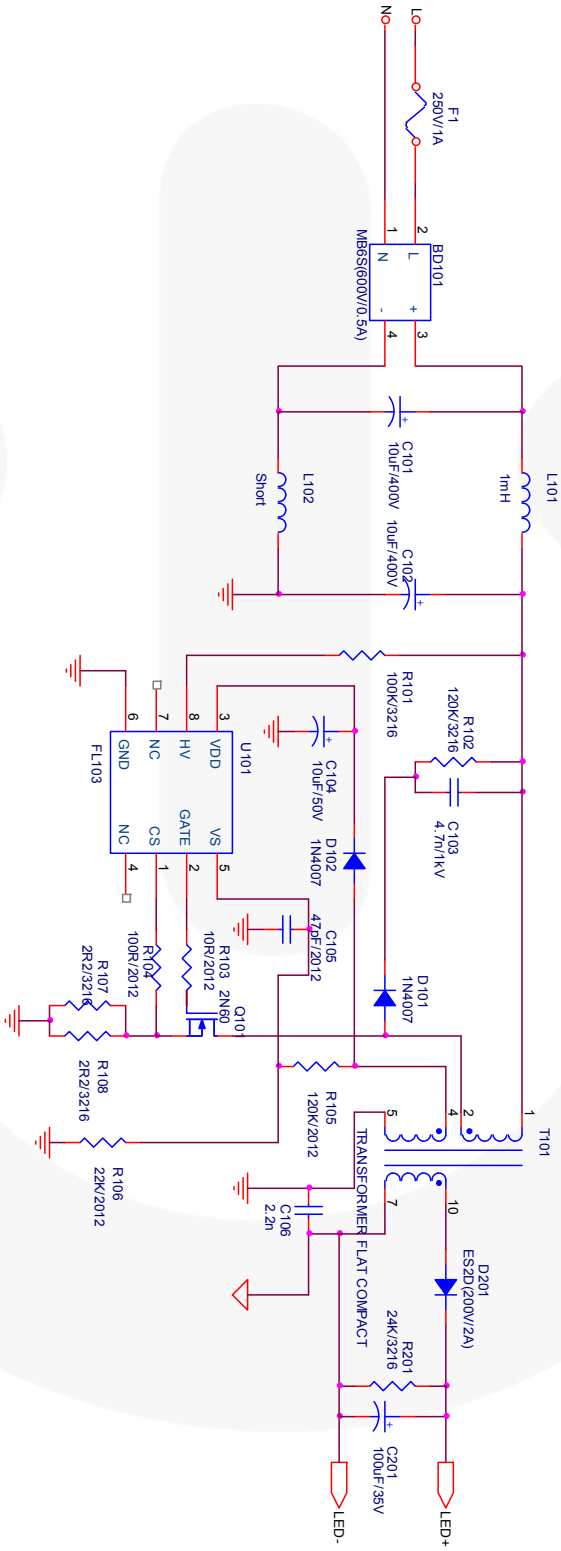


Figure 6. Evaluation Board Schematic

6. Bill of Materials

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
1	U101	FL103M	1	Controller, SOP-8	Fairchild Semiconductor
2	Q101	FQU2N60C	1	600 V / 2 A MOSFET, I-PAK,	Fairchild
3	T101	EE1614S	1	Transformer, Lm = 1.13 mH	TDK
4	F1	SS-5-1A	1	250 V / 1 A Fuse	Bussmann
5	L101	R08102KT00	2	1 mH Filter Inductor, 8Φ	Bosung
6	L102	Short	0	Short	
7	BD101	MB6S	1	600 V / 0.5 A Bridge Rectifier, SOIC-4	Fairchild Semiconductor
8	D101, D102	1N4007	2	1 kV / 1 A Rectifier, DO-41	Fairchild Semiconductor
9	D201	ES2D	1	200 V / 2 A Fast Rectifier, SMB/DO-214AA	Fairchild Semiconductor
10	C101, C102	KMG 10 µF / 400 V	2	10 µF / 400 V, Electrolytic Capacitor, 105°C	Samyoung
11	C103	3A472K	1	4.7 nF / 1 kV Ceramic Capacitor	Samwha
12	C104	KMG 10 µF / 50 V	1	10 µF /50 V, Electrolytic Capacitor, 105°C	Samyoung
13	C105	C0805C470J5GACTU	1	47 pF / 50 V, SMD Capacitor 2012	Kemet
14	C106	SCFz2E472M10BW	1	4.7 nF / 250 V Y-Capacitor	Samwha
15	C201	WB 100 µF/35V	1	100 µF / 35 V, Ultra-Low Impedance Electrolytic Capacitor, 105°C	Samwha
16	R101	RC1206JR-07100KL	1	100 kΩ SMD Resistor 3216	Yageo
17	R102	RC1206JR-07120KL	1	120 kΩ SMD Resistor 3216	Yageo
18	R103	RC0805JR-0710RL	1	10 Ω SMD Resistor 2012	Yageo
19	R104	RC0805JR-07100RL	1	100 Ω SMD Resistor 2012	Yageo
20	R105	RC0805JR-07120KL	1	120 kΩ SMD Resistor 2012	Yageo
21	R106	RC0805JR-0722KL	1	22 kΩ SMD Resistor 2012	Yageo
22	R107, R108	RC1206JR-072R2L	2	2.2 Ω SMD Resistor 3216	Yageo
23	R201	RC1206JR-0724KL	1	24 kΩ SMD Resistor 3216	Yageo

7. Transformer Design

- Core: EE1614S (PC-40)
- Bobbin: 10 Pins

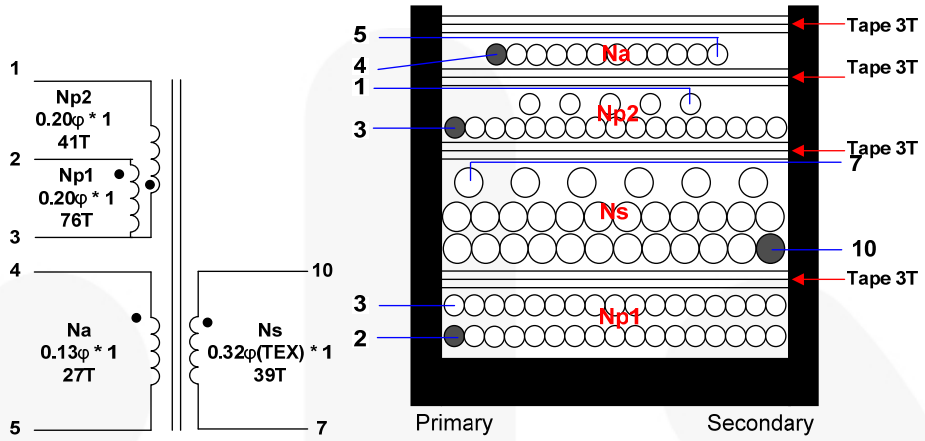


Figure 7. Transformer Specifications & Construction

Table 2. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	Np1	2 → 3	0.20 Φ * 1	76 Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.0 mm, 3-Layer				
3	Ns	10 → 7	0.32 Φ (TEX) * 1	39 Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.05 mm, 3-Layer				
5	Np2	3 → 1	0.20 Φ * 1	41 Ts	Solenoid Winding
6	Insulation: Polyester Tape t = 0.05 mm, 3-Layer				
7	Na	4 → 5	0.13 Φ * 1	27 Ts	Center Solenoid Winding
8	Outer Insulation: Polyester Tape t = 0.05 mm, 3-Layer				

Table 3. Electrical Characteristics

	Pin	Specification	Remark
Inductance	1 - 2	1.13 mH ±7%	1 kHz, 1 V
Leakage	1 - 2	Max. 20 μH	Short All Output Pins

8. Performance of Evaluation Board

Table 4. Test Conditions & Test Equipment

Test Temperature	T_A = 25°C
Test Equipments	AC Power Source: ES2000S by PSTATIONES Power Analyzer: DZ4000 by YOKOGAWA Electronic Load: PLZ303WH by KIKUSUI Automatic Power Tester: ATS3000 by BOB Multimeter: 2002 by KEITHLEY Oscilloscope: 104Xi by LeCroy EMI Test Receiver: ESCS30 by ROHDE & SCHWARZ Two-Line V-Network: ENV216 by ROHDE & SCHWARZ Thermometer: Therma CAM SC640 by FLIR SYSTEMS LED: EHP-AX08EL/GT01H-P03 (3 W) by Everlight

8.1. Input Power at Minimum Load Condition

Test Condition: Measure the input power and output voltage at open load; Yellow (V_{DS}), Red (V_{DD})

Table 5. Test Results

Input Voltage	Input Power	Output Voltage	Remark
85 V_{AC} / 60 Hz	0.092 W	26.62 V	< 0.3 W
110 V_{AC} / 60 Hz	0.094 W	26.63 V	
230 V_{AC} / 50 Hz	0.101 W	26.64 V	
265 V_{AC} / 50 Hz	0.091 W	26.27 V	

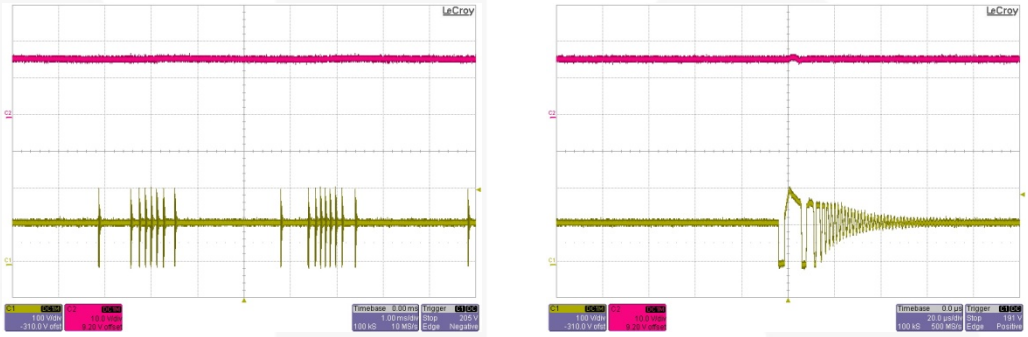


Figure 8. 85 V_{AC} / 60 Hz

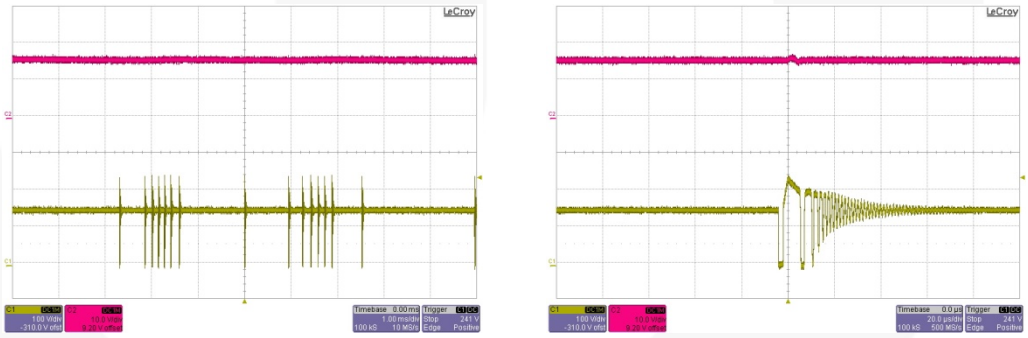


Figure 9. 110 V_{AC} / 60 Hz

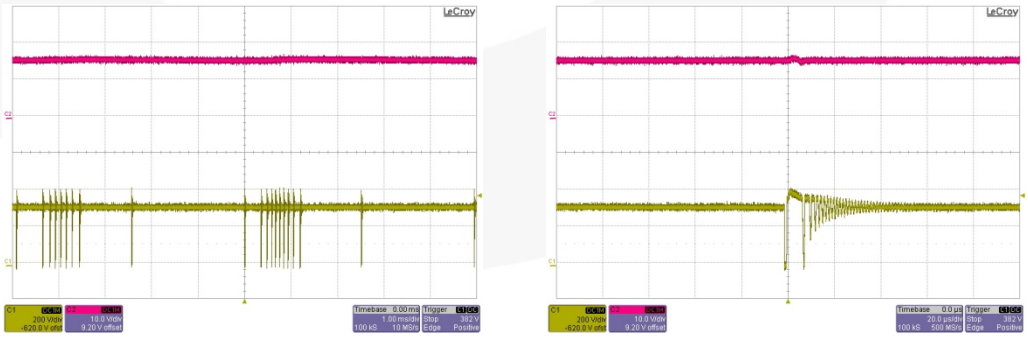


Figure 10. 230 V_{AC} / 50 Hz

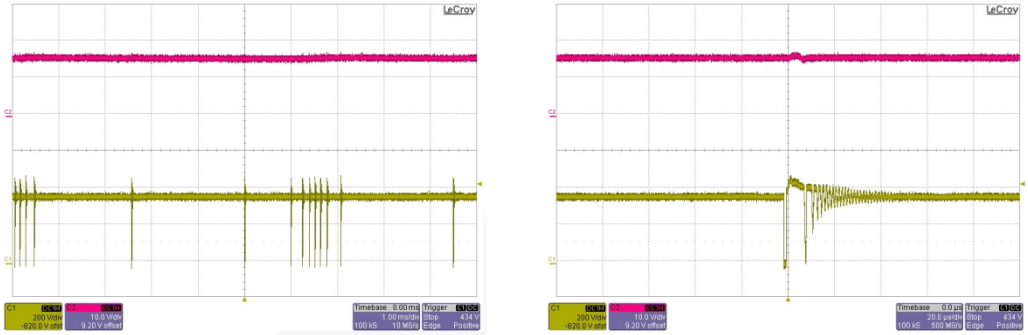


Figure 11. 265 V_{AC} / 50 Hz

8.2. Startup Time

Test Condition: Connect seven LEDs and measure the time interval between AC plug-in and stable output; Yellow (V_{DS}), Blue (V_O), Green (I_O)

Table 6. Test Results

Input Voltage	Turn-On Time
85 V_{AC} / 60 Hz	213 ms
110 V_{AC} / 60 Hz	160 ms
230 V_{AC} / 50 Hz	98 ms
265 V_{AC} / 50 Hz	96 ms

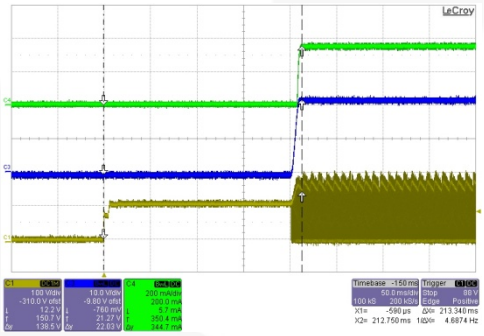


Figure 12. 85 V_{AC} / 60 Hz

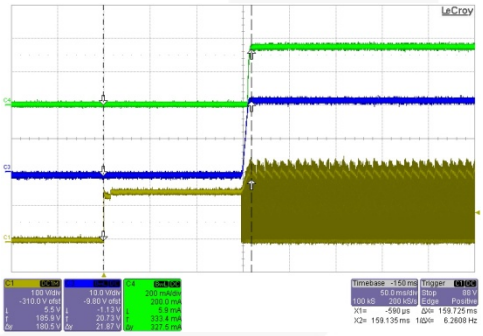


Figure 13. 110 V_{AC} / 60 Hz

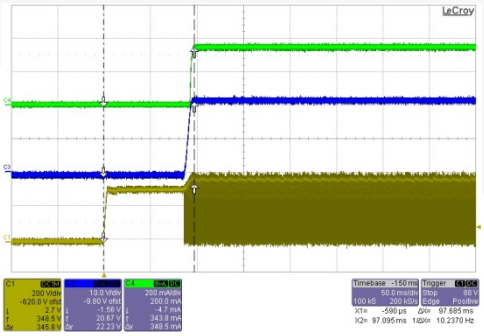


Figure 14. 230 V_{AC} / 50 Hz

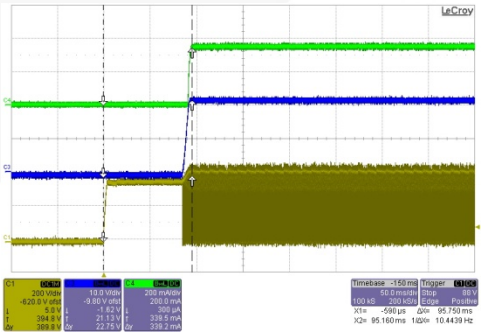


Figure 15. 265 V_{AC} / 50 Hz

8.3. Input Current

Test Condition: Connect seven LEDs and measure the AC input current; Yellow (V_{DS}), Red (V_{DD}), Green (I_O)

Table 7. Test Result

Input Voltage	Input Current
85 V_{AC} / 60 Hz	185 mA
110 V_{AC} / 60 Hz	155 mA
230 V_{AC} / 50 Hz	98 mA
265 V_{AC} / 50 Hz	92 mA

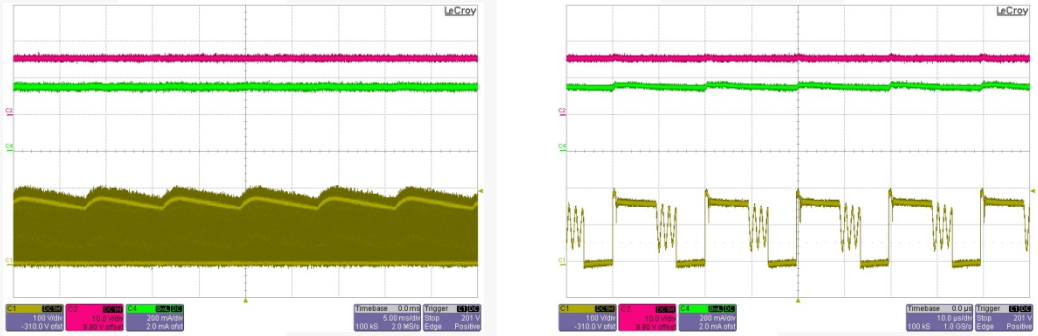


Figure 16. 85 V_{AC} / 60 Hz

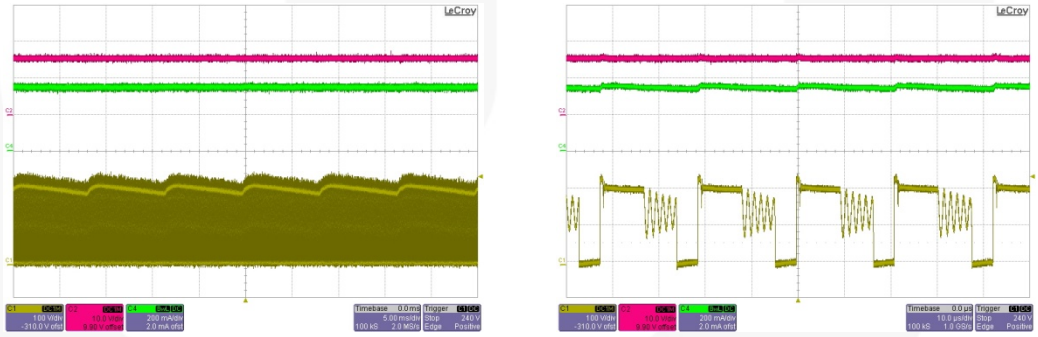


Figure 17. 110 V_{AC} / 60 Hz

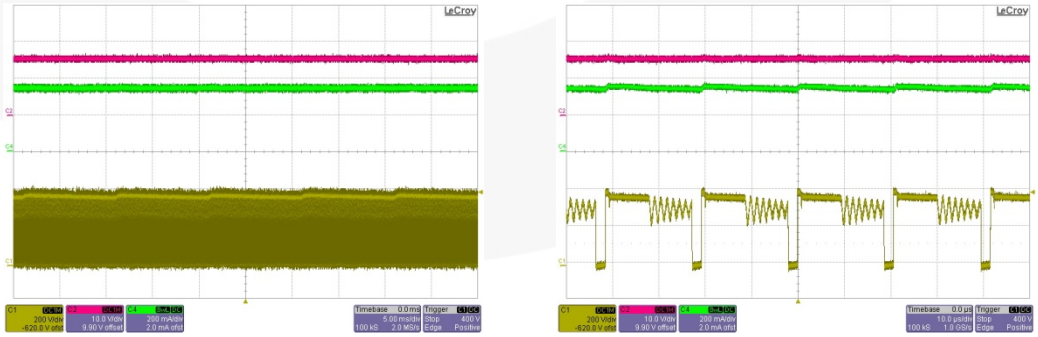


Figure 18. 230 V_{AC} / 50 Hz

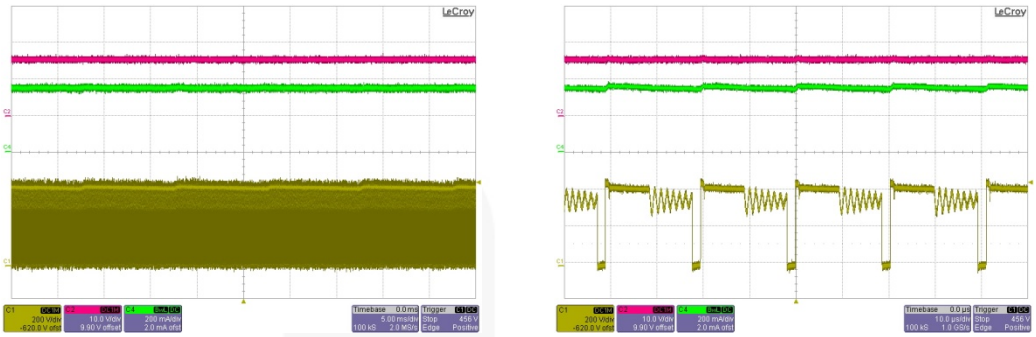


Figure 19. 265 V_{AC} / 50 Hz

8.4. Output Ripple & Noise

Test Condition: Connect seven LEDs. Ripple and noise are measured by using 20 MHz bandwidth limited oscilloscope with a 10 µF / 50 V capacitor paralleled with a high-frequency 0.1 µF capacitor across each output; Red (V_O), Green (I_O)

Table 8. Test Result

Input Voltage	Ripple Source	Voltage Ripple	Current Ripple
85 V_{AC}/ 60 Hz	AC Source	256 mV_{P-P}	30 mA_{P-P}
	Main Frequency	205 mV_{P-P}	27 mA_{P-P}
110 V_{AC} / 60 Hz	AC Source	218 mV_{P-P}	29 mA_{P-P}
	Main Frequency	211 mV_{P-P}	29 mA_{P-P}
230 V_{AC} / 50 Hz	AC Source	211 mV_{P-P}	27 mA_{P-P}
	Main Frequency	205 mV_{P-P}	29 mA_{P-P}
265 V_{AC} / 50 Hz	AC Source	224 mV_{P-P}	30 mA_{P-P}
	Main Frequency	198 mV_{P-P}	27 mA_{P-P}

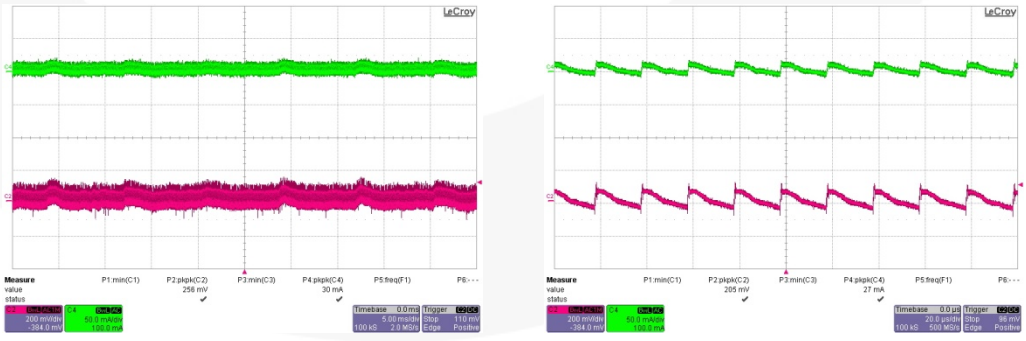


Figure 20. 85 V_{AC} / 60 Hz

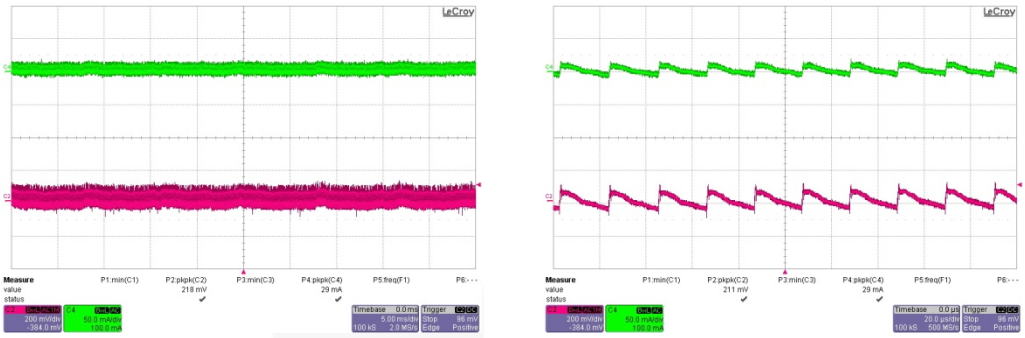


Figure 21. 110 V_{AC} / 60 Hz

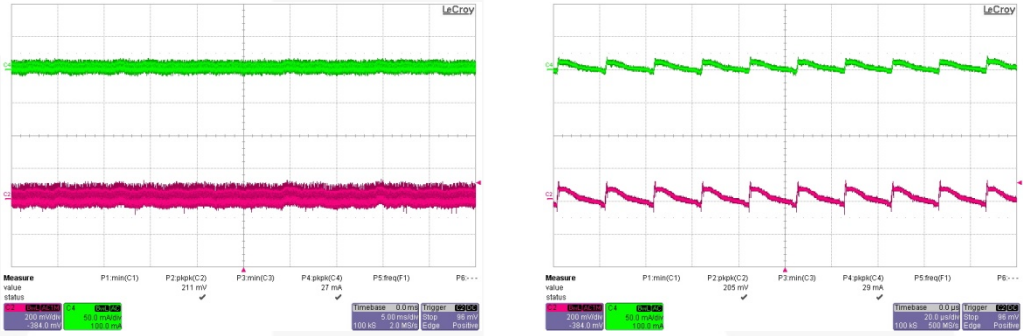


Figure 22. 230 V_{AC} / 50 Hz

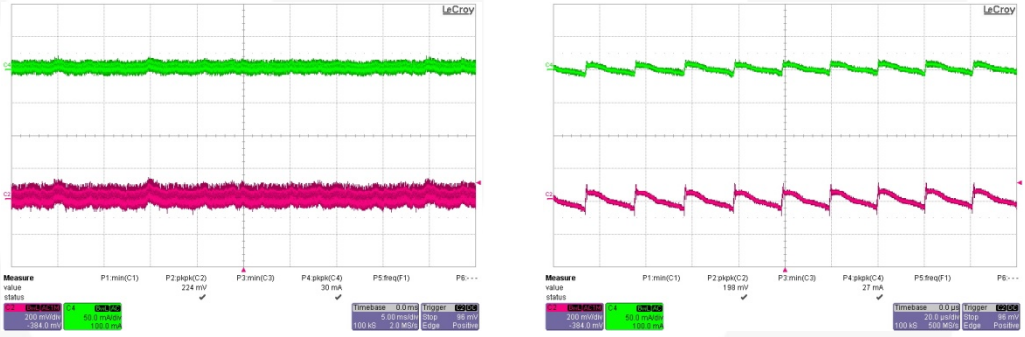


Figure 23. 265 V_{AC} / 50 Hz

8.5. Short-Circuit Protection (SCP)

Test Condition: Connect seven LEDs and measure input power on short-circuit in "Hiccup" Mode operation; Yellow (V_{DS}), Red (V_{DD}), Green (V_O)

Table 9. Test Results

Input Voltage	Input Power at SCP
85 V_{AC} / 60 Hz	0.116 W
110 V_{AC} / 60 Hz	0.180 W
230 V_{AC} / 50 Hz	0.426 W
265 V_{AC} / 50 Hz	0.520 W

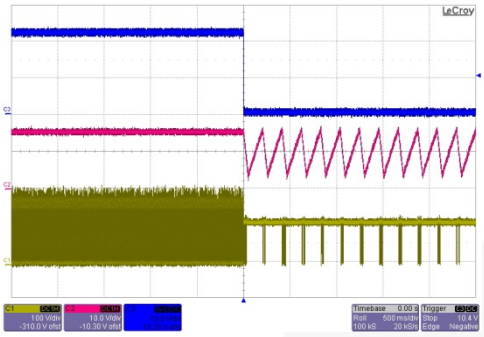


Figure 24. 230 V_{AC} / 60 Hz

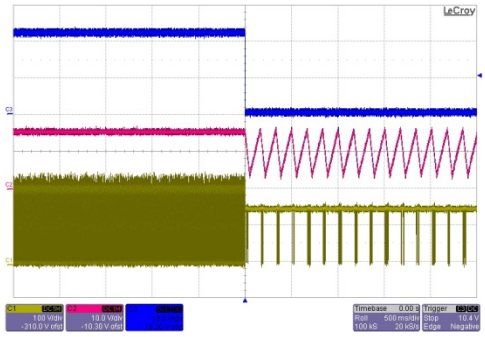


Figure 25. 110 V_{AC} / 60 Hz

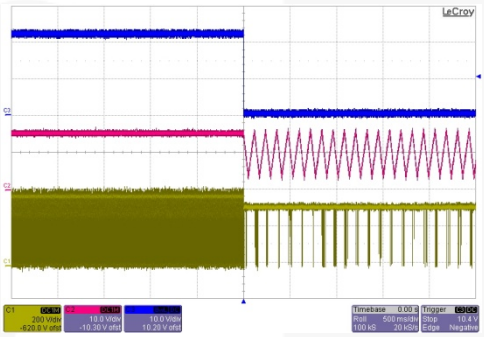


Figure 26. 230 V_{AC} / 50 Hz

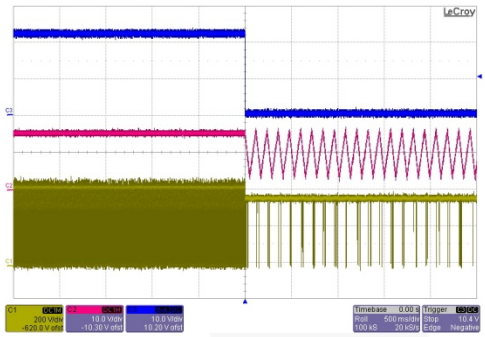


Figure 27. 265 V_{AC} / 50 Hz

8.6. Voltage & Current Stress on MOSFET

Test Condition: Connect seven LEDs and measure the voltage and current stress on the MOSFET; Yellow (V_{DS}), Green (I_D)

Table 10. Test Results

		85 V_{AC} / 60 Hz	110 V_{AC} / 60 Hz	230 V_{AC} / 50 Hz	265 V_{AC} / 50 Hz
Power On	**V**	217 V	247 V	430 V	478 V
	I	590 mA	590 mA	590 mA	590 mA
Normal	**V**	221 V	257 V	443 V	481 V
	I	606 mA	590 mA	606 mA	590 mA
Short Circuit	**V**	136 V	171 V	348 V	402 V
	I	290 mA	290 mA	380 mA	460 mA
Power Off	**V**	137 V	137 V	152 V	152 V
	I	580 mA	580 mA	580 mA	580 mA

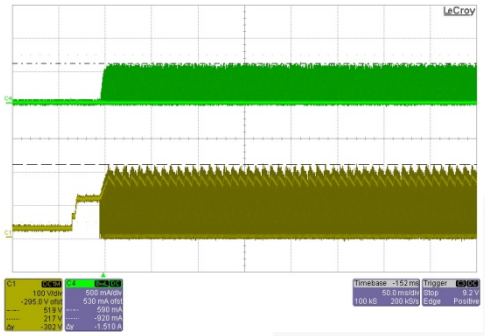


Figure 28. 85 V_{AC} / 60 Hz; Power On

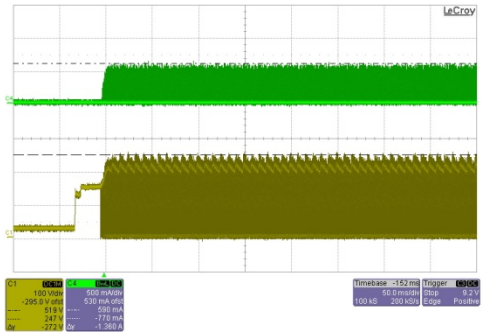


Figure 29. 110 V_{AC} / 60 Hz; Power On

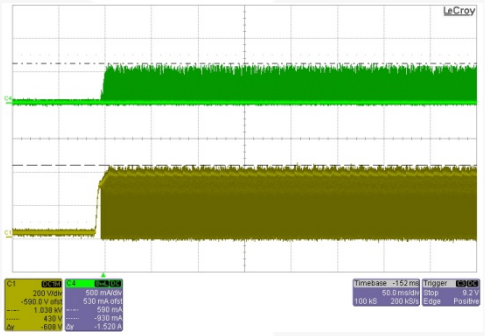


Figure 30. 230 V_{AC} / 50 Hz; Power On

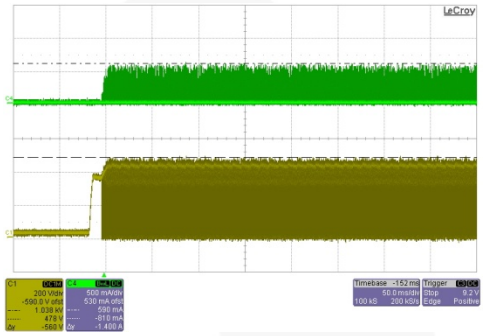


Figure 31. 265 V_{AC} / 50 Hz; Power On

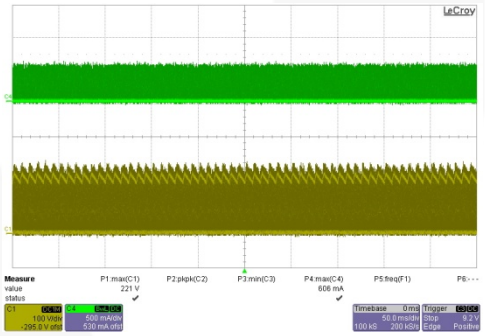


Figure 32. 85 V_{AC} / 60 Hz; Normal Operation

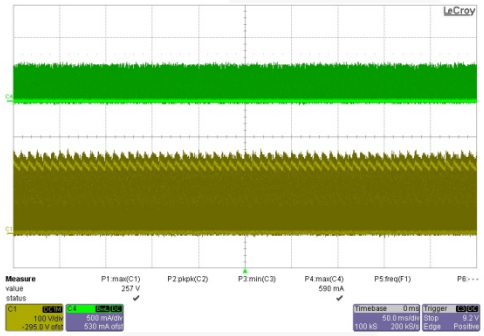


Figure 33. 110 V_{AC} / 60 Hz; Normal Operation

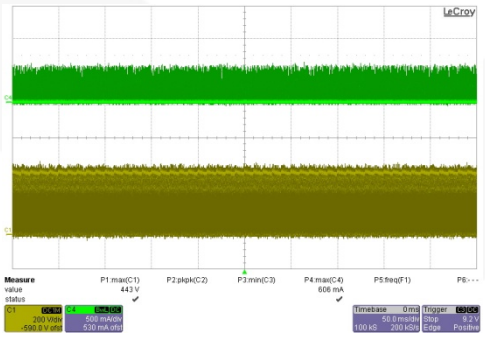


Figure 34. 230 V_{AC} / 50 Hz; Normal Operation

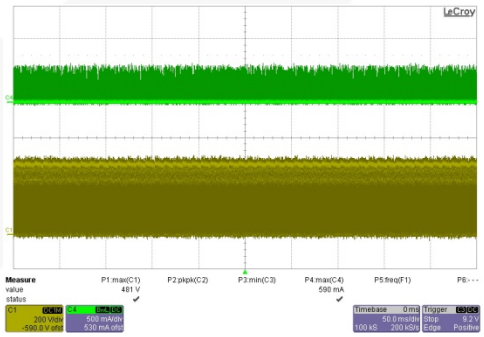


Figure 35. 265 V_{AC} / 50 Hz; Normal Operation

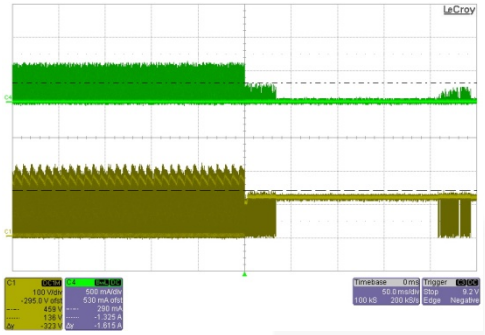


Figure 36. 85 V_{AC} / 60 Hz; Short Circuit

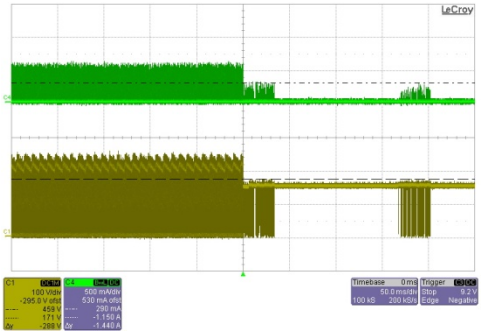


Figure 37. 110 V_{AC} / 60 Hz; Short Circuit

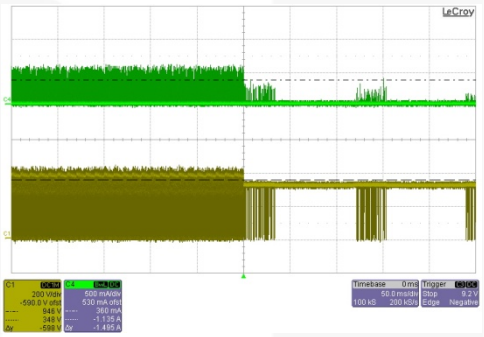


Figure 38. 230 V_{AC} / 50 Hz; Short Circuit

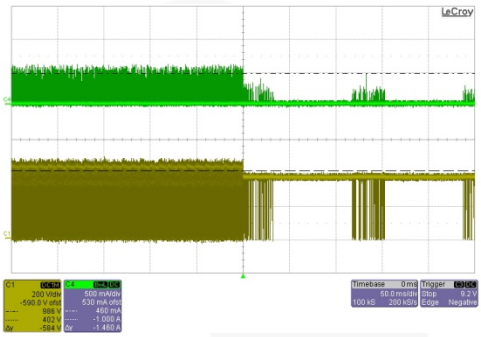


Figure 39. 265 V_{AC} / 50 Hz; Short Circuit

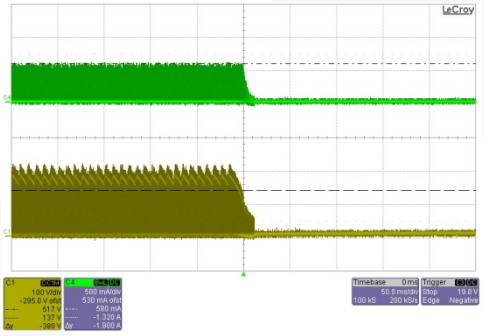


Figure 40. 85 V_{AC} / 60 Hz; Power Off

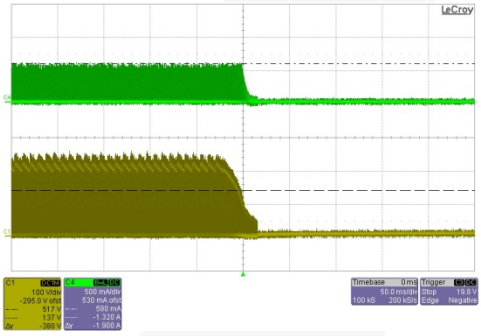


Figure 41. 110 V_{AC} / 60 Hz; Power Off

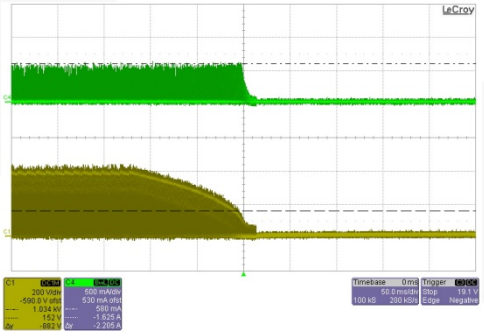


Figure 42. 230 V_{AC} / 50 Hz; Power Off

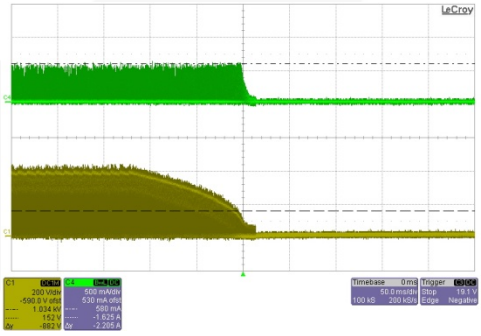


Figure 43. 265 V_{AC} / 50 Hz; Power Off

8.7. Voltage & Current Stress on Secondary Rectifier

Test Condition: Connect seven LEDs and measure the voltage and current stress on the secondary rectifier; Yellow (V_{AK}), Green (I_{AK})

Table 11. Test Results

		85 V_{AC} / 60 Hz	110 V_{AC} / 60 Hz	230 V_{AC} / 50 Hz	265 V_{AC} / 50 Hz
Power On	**V**	59.5 V	77.0 V	131.0 V	149.0 V
	I	2.48 A	2.28 A	2.28 A	2.28 A
Normal	**V**	68 V	79 V	136 V	161 V
	I	2.42 A	2.39 A	2.36 A	2.39 A
Short Circuit	**V**	79.5 V	97.0 V	170.0 V	176.0 V
	I	1.12 A	1.16 A	1.37 A	1.42 A
Power Off	**V**	38 V	38 V	45 V	45 V
	I	2.34 A	2.34 A	2.34 A	2.34 A

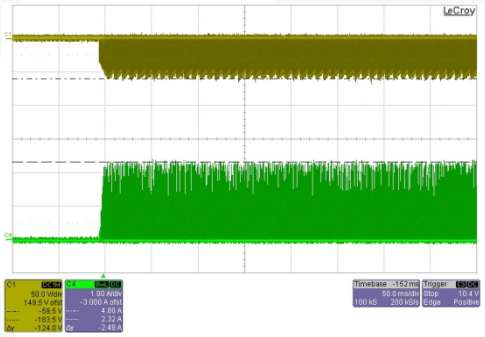


Figure 44. 85 V_{AC} / 60 Hz; Power On

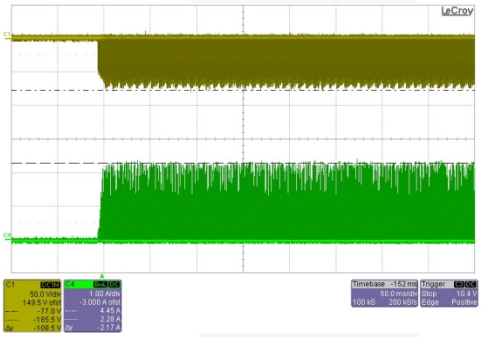


Figure 45. 110 V_{AC} / 60 Hz; Power On

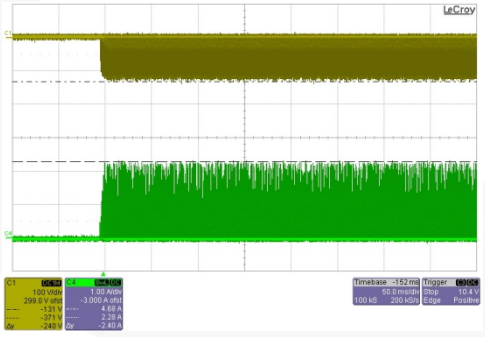


Figure 46. 230 V_{AC} / 50 Hz; Power On

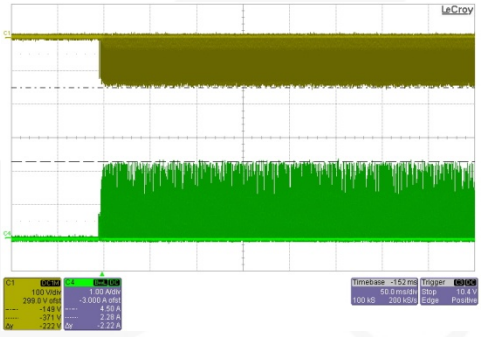


Figure 47. 265 V_{AC} / 50 Hz; Power On

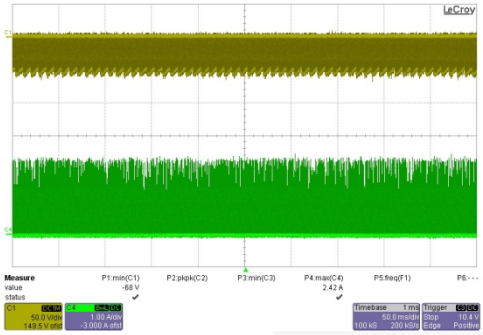


Figure 48. 85 V_{AC} / 60 Hz; Normal Operation

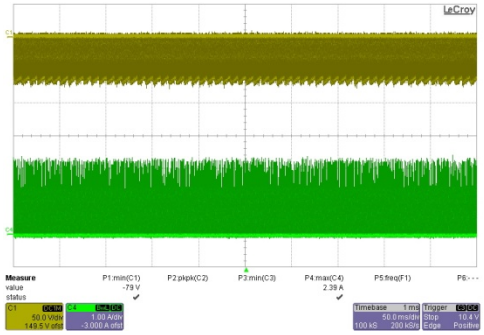


Figure 49. 110 V_{AC} / 60 Hz; Normal Operation

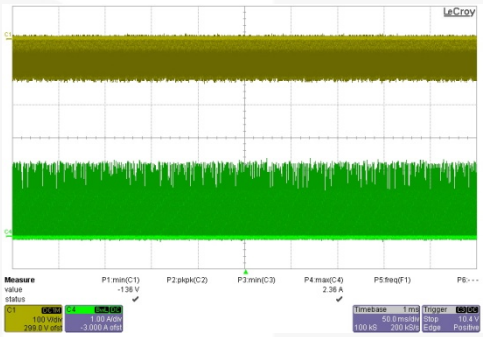


Figure 50. 230 V_{AC} / 50 Hz; Normal Operation

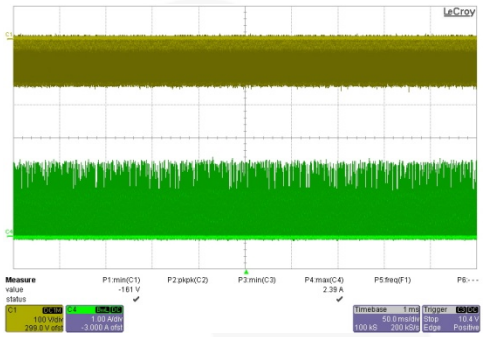


Figure 51. 265 V_{AC} / 50 Hz; Normal Operation

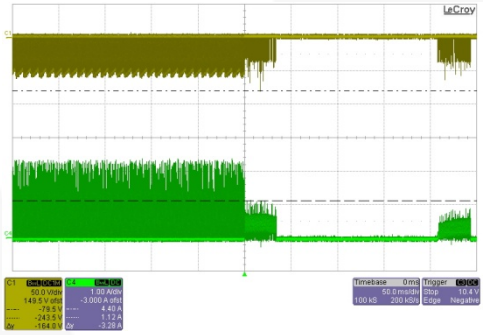


Figure 52. 85 V_{AC} / 60 Hz; Short Circuit

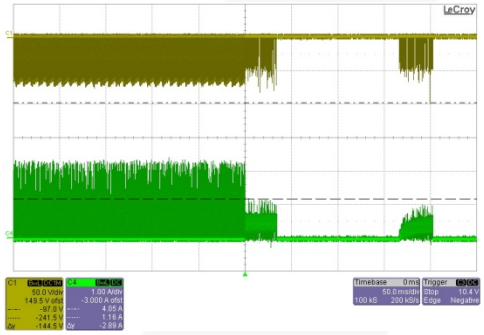


Figure 53. 110 V_{AC} / 60 Hz; Short Circuit

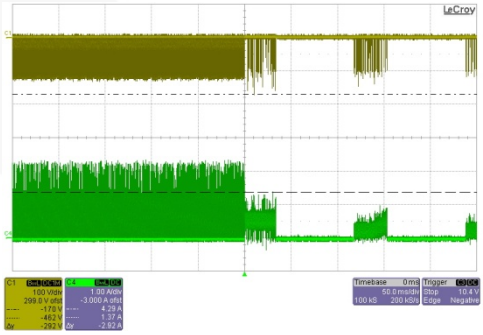


Figure 54. 230 V_{AC} / 50 Hz; Short Circuit

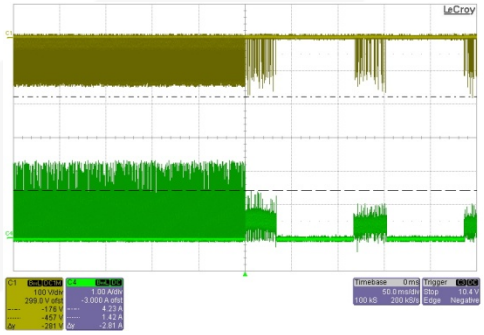


Figure 55. 265 V_{AC} / 50 Hz; Short Circuit

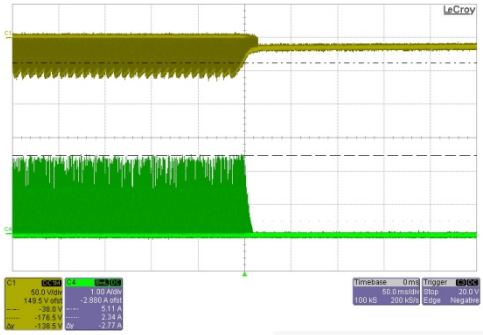


Figure 56. 85 V_{AC} / 60 Hz; Power Off

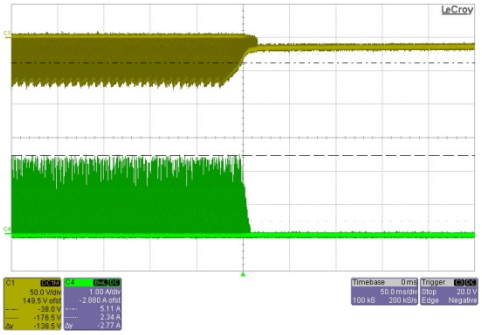


Figure 57. 110 V_{AC} / 60 Hz; Power Off

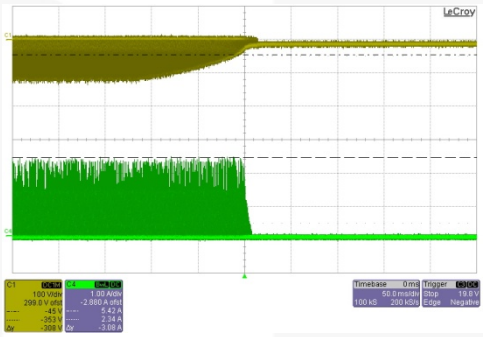


Figure 58. 230 V_{AC} / 50 Hz; Power Off

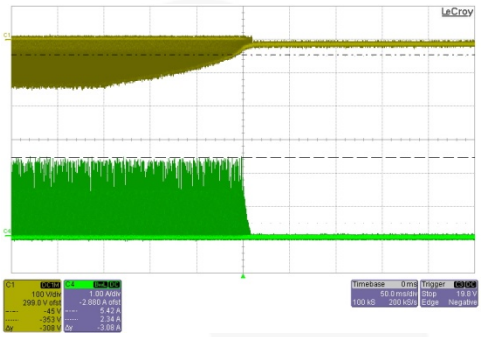


Figure 59. 265 V_{AC} / 50 Hz; Power Off

8.8. Constant Current Tolerance Using Electric Load (CR)

Test Condition: Aging five seconds at minimum load and measure the output current and output voltage. Load is CR mode of electric load.

Table 12. Test Results

Input Voltage	Minimum Current	Maximum Current	Tolerance	Remark
85 V_{AC} / 60 Hz	346 mA	350 mA	1.14%	< 10%
110 V_{AC} / 60 Hz	346 mA	348 mA	0.57%	
230 V_{AC} / 50 Hz	343 mA	350 mA	2.00%	
265 V_{AC} / 50 Hz	343 mA	349 mA	1.72%	
Total	343 mA	350 mA	2.00%	

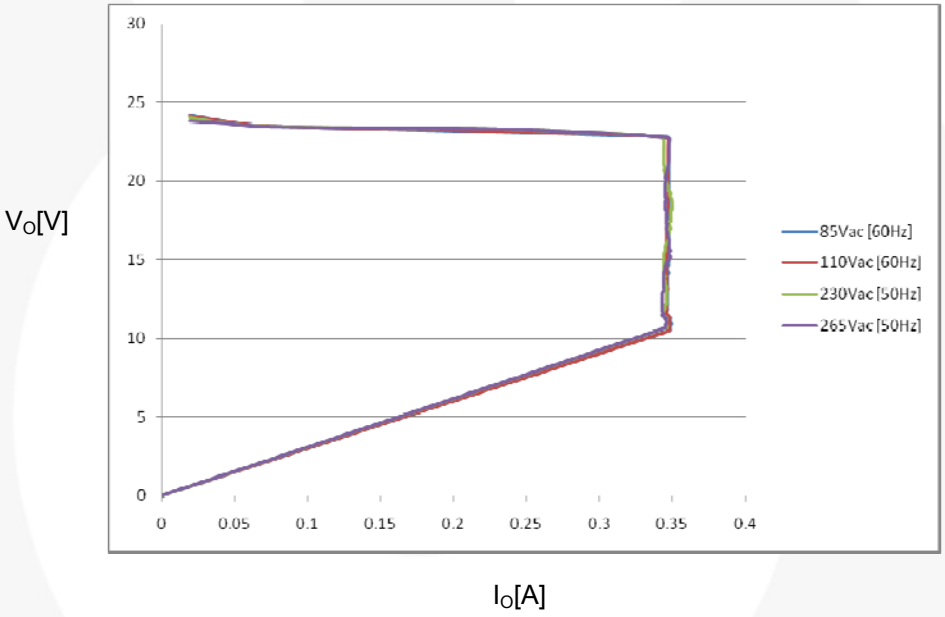


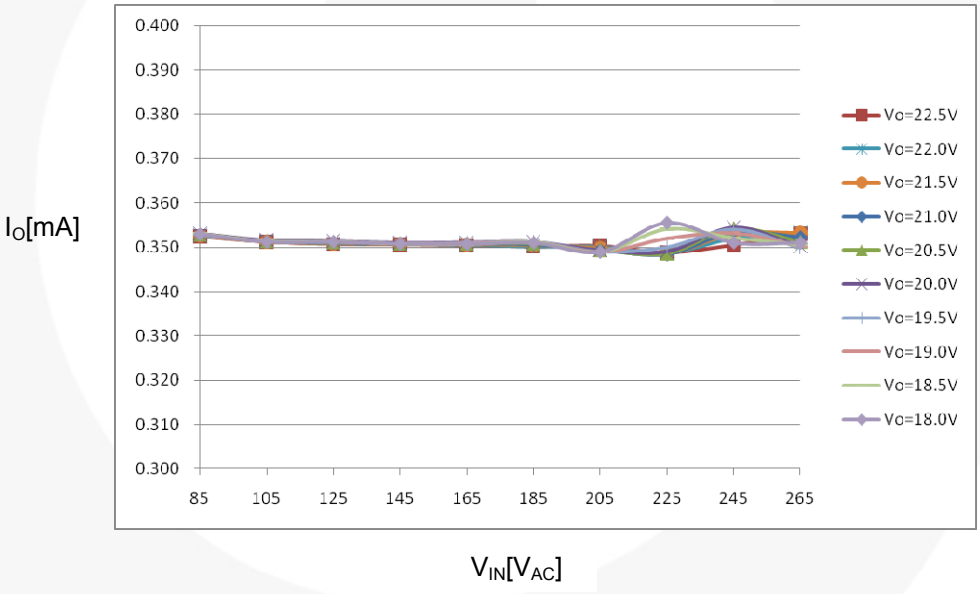
Figure 60. CC / CV Curve

8.9. Constant Current Tolerance Using Electric Load (CV)

Test Condition: Fixed output voltage and variable input voltage. Measure output current. Load is CV mode of electric load.

Table 13. Deviation by Input Voltage

V_O[V]	Min. Current	Max. Current	Tolerance	Remark
22.5	349 mA	353 mA	1.19%	< 10%
22.0	349 mA	353 mA	1.27%	
21.5	349 mA	353 mA	1.33%	
21.0	348 mA	354 mA	1.44%	
20.5	349 mA	353 mA	1.61%	
20.0	349 mA	355 mA	1.55%	
19.5	349 mA	354 mA	1.41%	
19.0	349 mA	353 mA	1.22%	
18.5	349 mA	354 mA	1.47%	
18.0	349 mA	356 mA	1.86%	
Total	348 mA	356 mA	2.02%	



I_O[mA]

V_{IN}[V_{AC}]

Figure 61. Deviation Curve

8.10. Constant Current Toleration Using LED Load

Test Condition: Age five minutes at 85 V_{AC} and measure the output current and output voltage. Load is LED.

Table 14. Deviation by Input Voltage

LEDs	Minimum Current	Maximum Current	Tolerance	Remark
7-LED	343 mA	347 mA	1.27%	< 10%
6-LED	343 mA	348 mA	1.52%	
5-LED	342 mA	349 mA	2.01%	
4-LED	347 mA	350 mA	1.06%	

Table 15. Deviation by All Conditions (LEDs & Input Voltage)

Input Voltage	Minimum Current	Maximum Current	Tolerance
85 V_{AC}	346 mA	349 mA	0.92%
105 V_{AC}	345 mA	348 mA	1.03%
125 V_{AC}	345 mA	348 mA	1.06%
145 V_{AC}	345 mA	348 mA	0.86%
165 V_{AC}	344 mA	348 mA	0.89%
185 V_{AC}	342 mA	350 mA	2.34%
205 V_{AC}	343 mA	349 mA	1.78%
225 V_{AC}	343 mA	348 mA	1.55%
245 V_{AC}	344 mA	347 mA	0.78%
265 V_{AC}	345 mA	349 mA	1.18%
Total	342 mA	350 mA	2.34%

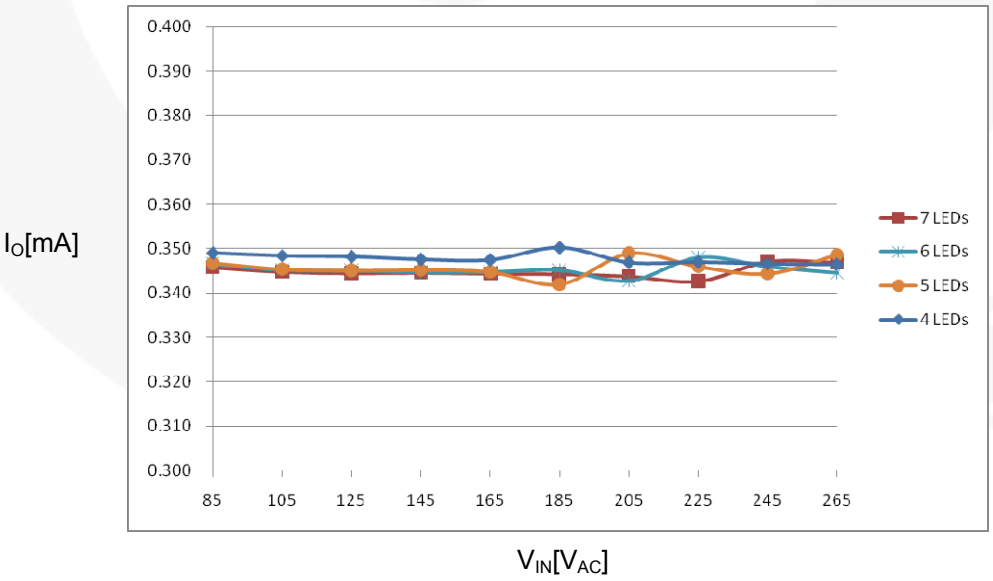


Figure 62. Deviation Curve

8.11. Efficiency

Test Condition: Connect seven LEDs and measure the input and output power after 30 minutes aging.

Table 16. Test Results

Input Voltage	Input Power	Output Power	Efficiency
85 V_{AC} / 60 Hz	8.781 W	7.460 W	84.96%
110 V_{AC} / 60 Hz	8.626 W	7.440 W	86.24%
230 V_{AC} / 50 Hz	8.464 W	7.372 W	87.10%
265 V_{AC} / 50 Hz	8.617 W	7.490 W	86.92%

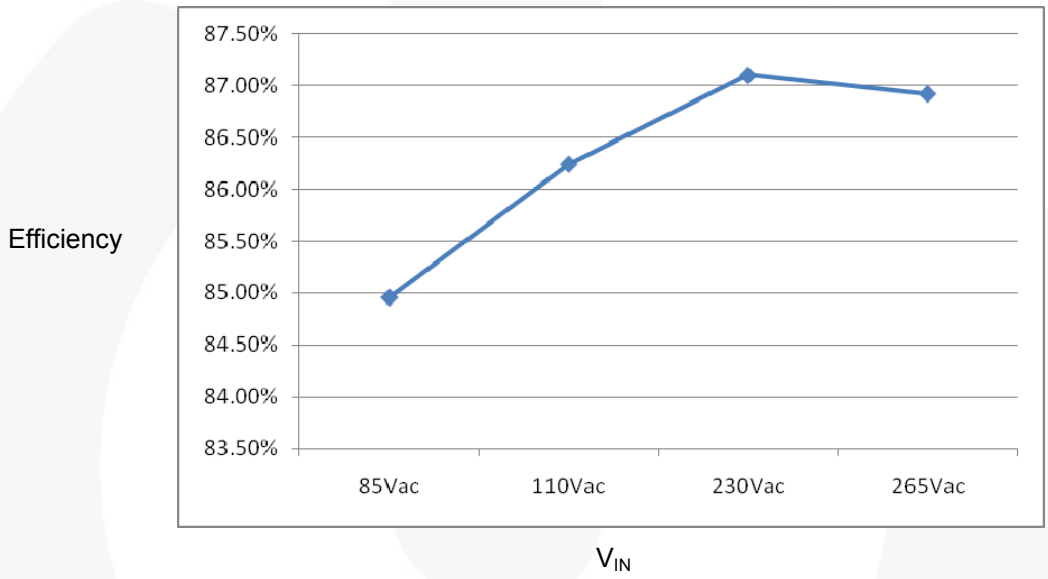


Figure 63. Efficiency Curve

8.12. Operating Temperature

Test Condition: Connect seven LEDs and measure the saturated temperature.

Table 17. Test Results

	85 V_{AC} / 60 Hz	265 V_{AC} / 50 Hz	Remark
MOSFET	50.8°C	48.4°C	Top-Side Circle
Transformer	50.7°C	51.5°C	Top-Side Box
RCD Snubber	50.2°C	49.0°C	Top-Side Spot
FL103M	45.9°C	42.8°C	Bottom-Side Circle
Secondary Rectifier	59.2°C	58.9°C	Top-Side Box
Current-Sense Resistors	39.9°C	39.5°C	Bottom-Side Spot

Temperature Photos

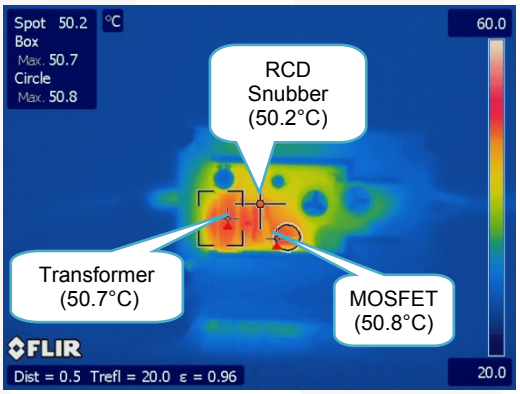


Figure 64. 85 V_{AC} / 60 Hz; Top Side

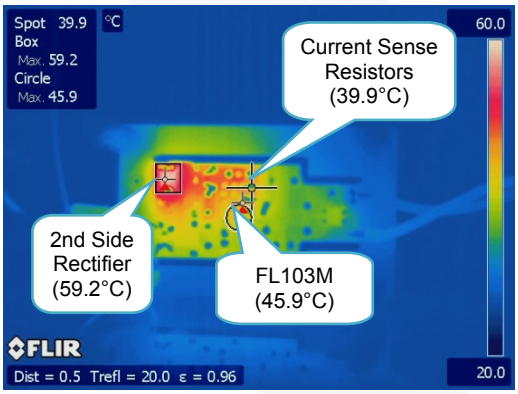


Figure 65. 85 V_{AC} / 60 Hz; Bottom Side

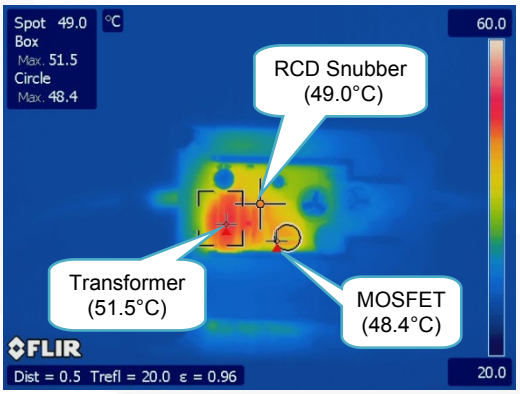


Figure 66. 265 V_{AC} / 50 Hz; Top Side

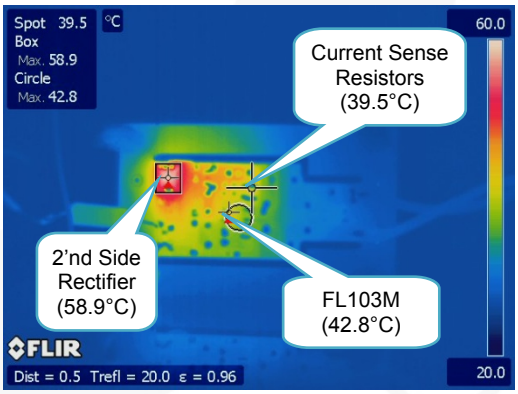


Figure 67. 265 V_{AC} / 50 Hz; Bottom Side

8.13. Electromagnetic Interference (EMI)

Test Conditions:

- Frequency Subrange: 150 kHz – 30 MHz,
- Measuring: QuasiPeak; Average
- Load is 7 LEDs

Table 18. Test Results

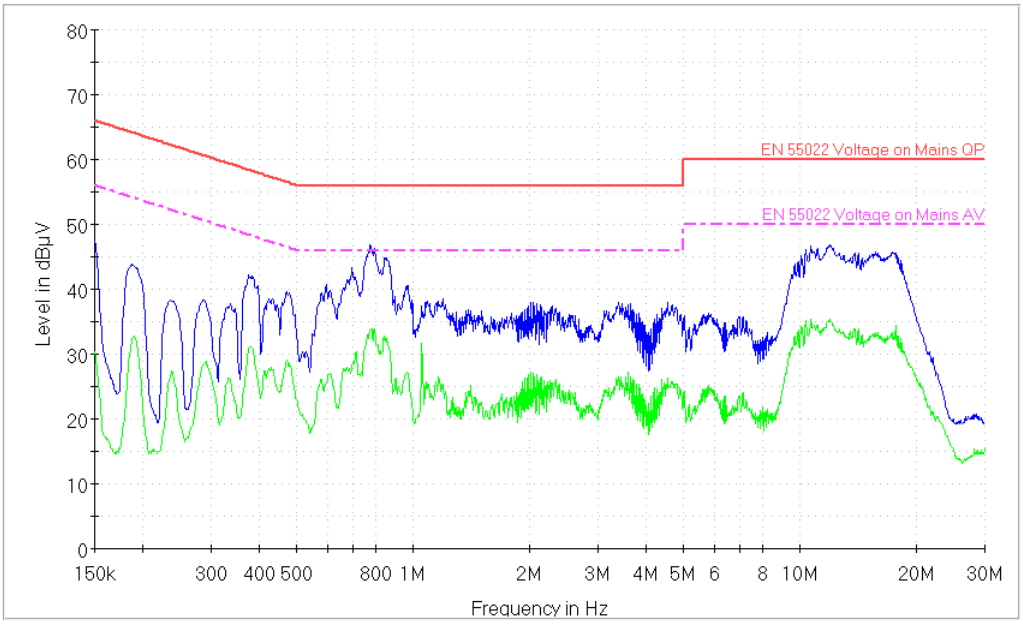


Figure 68. Conduction Line: 110 V_{AC} / 60 Hz

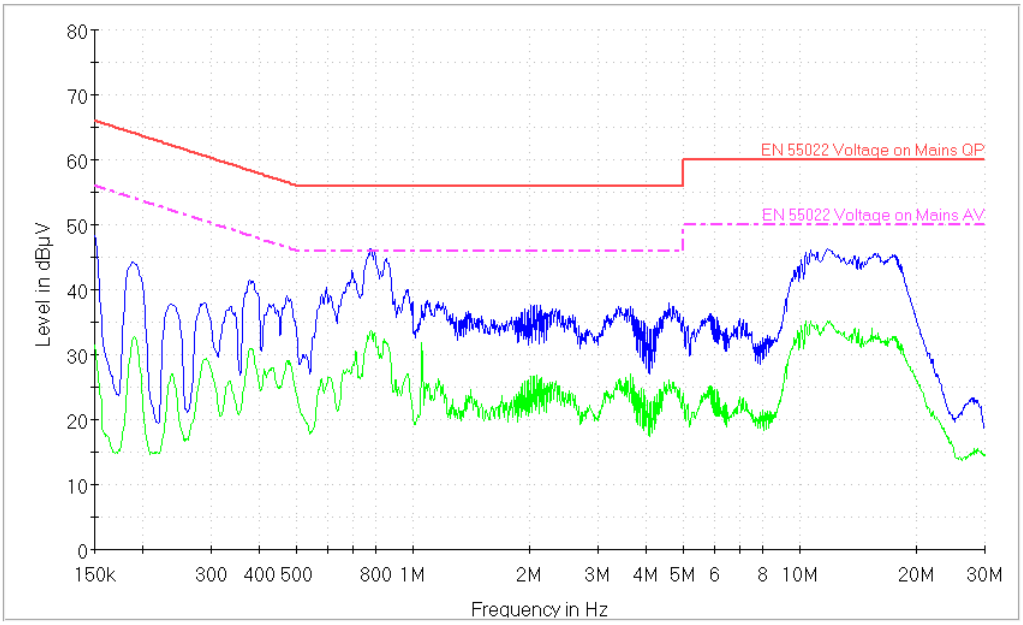


Figure 69. Conduction Neutral: 110 V_{AC} / 60 Hz

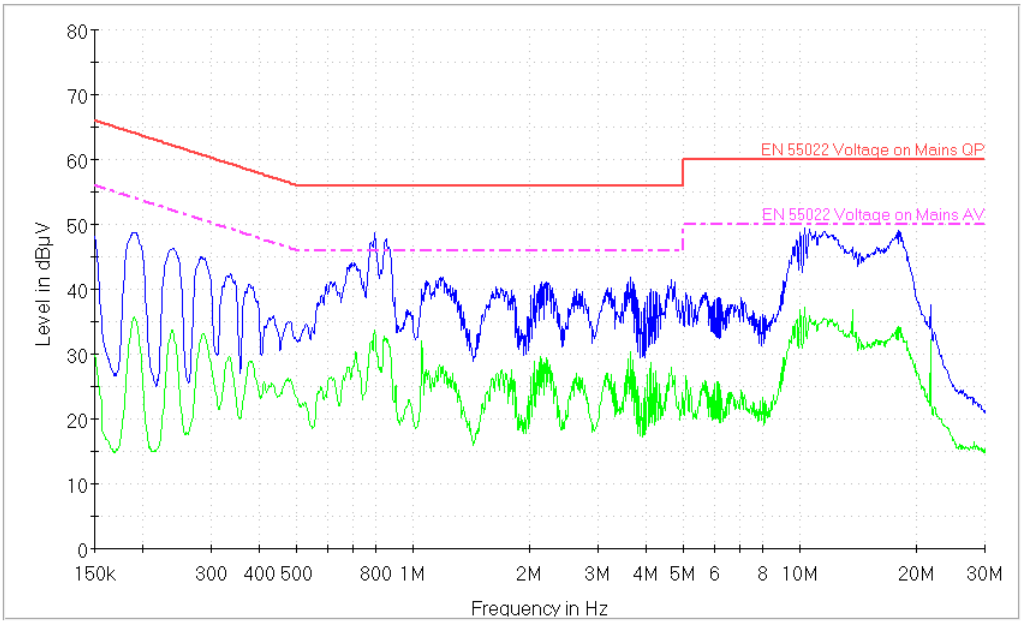


Figure 70. Conduction Line: 220 V_{AC} / 60 Hz

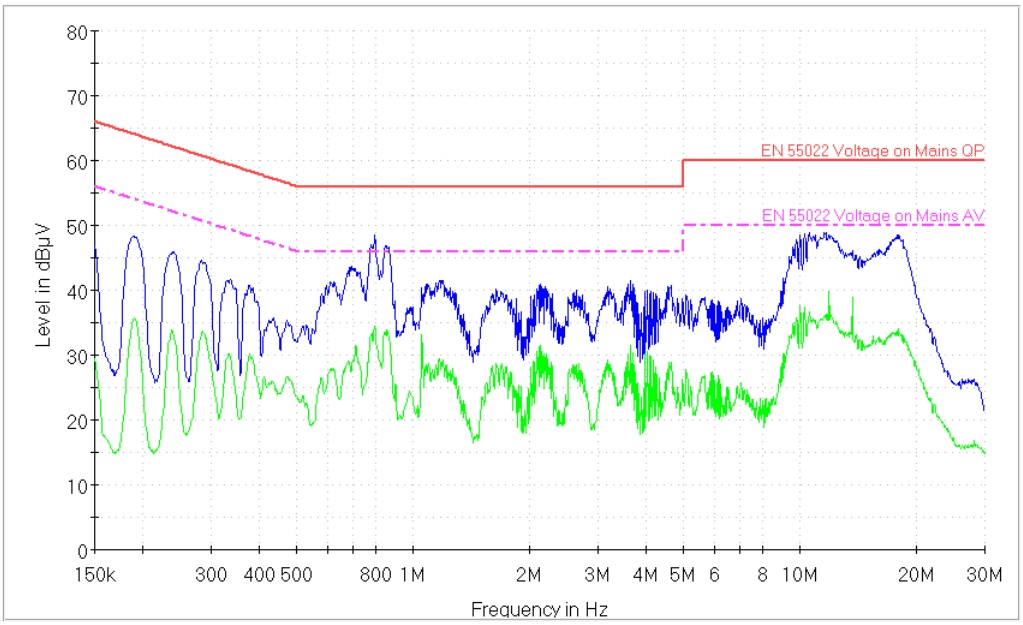


Figure 71. Conduction Neutral: 220 V_{AC} / 60 Hz

9. Revision History

Rev.	Date	Description
1.0.0	June 2011	Initial Release
1.0.1	July 2011	Reduced PCB Type & Size: Square → Bulb, 62 x 41 mm^2 → 53 x 25 mm^2
1.0.2	May 2012	Update Block Diagram & BOM
1.0.3	Oct. 2012	Modified, edited, formatted document. Changed User Guide number from FEB-L015 to FEBFL103_L15U008A

WARNING AND DISCLAIMER

Replace components on the Evaluation Board only with those parts shown on the parts list (or Bill of Materials) in the Users' Guide. Contact an authorized Fairchild representative with any questions.

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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